ALBERTA OFFICE OF COAL RESEARCH & TECHNOLOGY

ANNUAL REVIEW 1984/85

ALBERTA ENERGY AND NATURAL RESOURCES

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CONTENTS

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ENERGY AND
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INTRODUCTION

The Alberta Office of Coal Research and Technology was established on January 20, 1984 by Ministerial Order under the Department of Energy and Natural Resources Act. Its purpose is to encourage the development and application of new technologies related to Alberta's coals, which will improve coal exploration, production and transportation and increase use and marketability.

Initial appointments to the Office were R. Douglas McDonald as Chairman, and Keith E. Cooper and Garnet T. Page as Members. Keith E. Cooper served until March 1985; Michael A. Ward was appointed Member in May, 1985. T. David Brown represents Energy, Mines and Resources, Canada as an observer and participates in project reviews.

Initial funding of $20 million has been allocated from Alberta/Canada Energy Resources Research Fund to provide financial support for research projects.

'A successful Alberta Coal Research Strategy depends on the wise collaboration of government, industry and the university community.'

CHAIRMAN'S REPORT

Since its establishment in January 1984, the Alberta Office of Coal Research and Technology has been pursuing several activities important to the efficient and productive achievement of its purpose. It is my pleasure to provide this first Annual Report describing these activities.

One activity was to establish appropriate administrative procedures for the assessment of proposals for new research projects, the administration of research agreements and the establishment of appropriate financial controls. I would like to acknowledge the assistance of other divisions of Alberta Energy and Natural Resources and other departments and agencies of the Alberta government, including the representatives of the Interdepartmental Group for Coal Research, in helping to implement these procedures. The willingness of the Alberta Oil Sands Technology and Research Authority (AOSTRA) to share its experience in establishing a similar research organization has been most helpful.

A second important task has been to establish liaison with other groups involved in coal research and development within Alberta, across Canada and internationally. A publicity release describing the establishment and program of the Office stimulated an active response. Discussions regarding the role of the Office have been held with other departments and agencies of the Alberta government; The Coal Association of Canada; the Alberta universities; Energy, Mines and Resources, Canada; and numerous companies and individuals. The importance of fostering closer co-operation in order to overcome the current problems limiting the development of Alberta's coal resources is stressed. An important element is the need to have adequate knowledge of other coal-related research and development activities throughout the world. The assistance of the Coal Technology Information Centre at the Alberta Research Council and the Coal Technology Information Division of Energy, Mines and Resources, Canada is recognized.

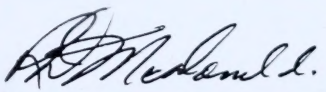
The response of the private sector to the establishment of the Alberta Office of Coal Research and Technology has been encouraging. Six new research projects proposed by various companies have been approved and 12 additional proposals are being assessed. These new projects reflect the interests of the coal industry in coal upgrading and combustion and the use of geophysical techniques to improve mine planning.

In addition to the specific projects initiated by the private sector, the Alberta Office of Coal Research and Technology, with co-operation from the coal industry, has established the Alberta Coal Research Grants Program, directed primarily at the universities, to stimulate excellence in fundamental coal research that will lead to placing Canadian coal technology in a position of world leadership. The first competition resulted in awarding financial assistance totalling $427 500 over three years for six research projects.

Finally, the progress of coal-related research projects, previously funded either directly by the Government of Alberta or through the Alberta/Canada Energy Resources Research Fund (A/CERRF), is being monitored and a number of long-standing concerns are being addressed.

The Office faces many challenges in assisting the coal producers of the province to maintain and enhance their competitiveness. It is firmly committed to encouraging the necessary concerted action by industry, government and the research community to identify, develop and apply the new technologies to permit the full realization of the economic potential of Alberta's coal deposits. It must be recognized, however, that the coal industry is facing a difficult period and while current research and development efforts will help to overcome the problems, the major effects can only be expected in the 1990s.

The increasing public concern over acid deposition and the apparent links to coal combustion are placing increasing emphasis on the need to identify, develop and demonstrate technologies to reduce the undesirable atmospheric emissions associated with coal use. This is becoming an area of increasing concern for the Alberta Office of Coal Research and Technology.



R. Douglas McDonald
Chairman

PROGRAM SUMMARY

This first annual report covers the 15-month period from January 20, 1984 to March 31, 1985. The first part of the report focuses on activities directed to achieving three priorities. The first priority was to establish goals and strategies for the operation of the Office. The second was to establish contact with other organizations and individuals involved in coal-related research. The third priority was to establish an administrative framework to review and monitor research proposals and administer funds. The second part of the report outlines the research projects in which the Office is participating.

ESTABLISHING GOALS

Alberta Coal Research Strategic Plan

The Alberta Office of Coal Research and Technology was established to implement the goals and strategies outlined in the *Alberta Coal Research Strategic Plan*.

These goals are to identify, investigate and develop those coal-related technologies considered likely to be commercially important during the next decade and which will:

- enhance the competitiveness of Alberta's coals in international markets
- minimize the environmental impact of the production or use of coal in Alberta
- result in new uses for Alberta's coals

Consistent with the views of the Government of Alberta, the Office believes that the private sector should take the leadership for the identification and management of appropriate research and development programs and for the final implementation and commercialization of results. The role of the Alberta Office of Coal Research and Technology, other government agencies such as the Alberta Research Council, the universities, and research organizations such as the Coal Mining Research Company is to support the private sector to achieve the necessary technical results in the most efficient manner.

While recognizing the need for both longer term research and development and fundamental research related to a better understanding of coal properties and uses, the critical time for commercial expansion and economic development of the province's coal resources is the intermediate time period from 1988 to 1998. During this time major growth in thermal coal use throughout the world is projected and increased competition can be expected from other coal-exporting countries. Other energy supplies, particularly natural gas and nuclear power, and the relative social and environmental acceptance of coal will have a major impact on the total thermal coal demand during this period.

New initiatives are required now, to ensure that Alberta coal achieves a maximum economic impact during the next 15 years. Toward this end, the Alberta Office of Coal Research and Technology, through the Alberta/Canada Energy Resources Research Fund, has identified initial funding of approximately $20 million in support of agreed research, development or demonstration projects. It is anticipated that similar funding will be forthcoming from the private sector in support of this strategy. Some portion of the funding will be identified for longer term or fundamental research directed toward new and innovative technologies related to the production and use of Alberta coals.

Alberta must collaborate closely with research groups in other provinces and countries to ensure that maximum benefit is derived from the total international coal research and development efforts, and to define its intermediate- and long-term plans within this context.

Coal Research and Development Priorities

The Alberta Office of Coal Research and Technology works closely with The Coal Association of Canada to establish research and development priorities. The Research and Development Committee of The Coal Association of Canada prepared a list of topics of importance to the coal industry. Highest priority is given to aspects of coal beneficiation, preparation and utilization.

The Office is taking steps to follow up on this initiative of The Coal Association of Canada and to identify an appropriate mechanism to achieve a closer matching between government-supported research and development activities and the needs of the coal industry.

An important role of the Office is to develop means to facilitate the transfer of new technology from research results to commercial realization. A process is being established to identify new opportunities and to bring these opportunities to the attention of the coal industry.

ESTABLISHING A RESEARCH COMMUNITY

A second activity of the Alberta Office of Coal Research and Technology in the first 15 months of operation was to establish contact with individuals and organizations involved in coal-related research and development.

Universities

Following meetings with representatives of the three Alberta universities, the Chairman of the Alberta Office of Coal Research and Technology met with faculty members involved in coal research to discuss the role of the universities within the scope of the Alberta Coal Research Strategic Plan. Topics included the relationship of the university researchers to the coal industry, the types of coal research being done in the universities and the importance of long-term fundamental research.

The **Coal Research Grant Program** was established as a result of these discussions. Its purpose is **to encourage scientific excellence in fundamental research related to coal, with the objective of placing Canadian coal technology in a position of world leadership.** A Coal Research Technical Panel, with representatives from the three Alberta universities, the Alberta Research Council, The Coal Association of Canada and the Alberta Office of Coal Research and Technology was established to evaluate research grant applications.

The first competition under this program was held in January 1985. The Office subsequently approved awards to six applicants from Alberta universities.

Consulting Groups

The Alberta Office of Coal Research and Technology is working with the Consulting Engineers of Alberta to develop a list of engineering skills available for coal research, development and project work in the province.

National and International Initiatives

The Alberta Office of Coal Research and Technology has contacted those engaged in coal-related research in Canada and internationally to describe the establishment and purpose of the Office. The Office plans to maintain these world-wide contacts.

Technical Information Sources

In addition to organizational contacts, the Alberta Office of Coal Research and Technology is examining several sources of relevant technical information to determine the best methods of utilizing them.

ESTABLISHING AN ADMINISTRATIVE FRAMEWORK

An important task for the Alberta Office of Coal Research and Technology was to establish an administrative structure and operating procedures. The Office operates under Rules of Procedure approved by the Minister of Energy and Natural Resources for the conduct of its business.

The source of initial funding for the Office is primarily from the Alberta/Canada Energy Resources Research Fund and is made available through the annual budget approvals of the Alberta Government.

The Alberta/Canada Energy Resources Research Fund (A/CERRF) was created as a result of the March 1974 agreement between the producing provinces and the Government of Canada to hold the wellhead price of domestic crude oil at $6.50 per barrel from April 1, 1974 to June 30, 1975. In recognition of Alberta's agreement to sell its crude oil below international prices, the federal government committed itself to provide increased funds to assist in strengthening and diversifying the Alberta economy, a portion of which was identified for energy-related research.

A Financial Operating Plan has been established which describes the operating practices of the Alberta Office of Coal Research and Technology in regards to receipt, review and approval of research proposals, the subsequent monitoring of approved research projects and the payment of invoices to reimburse the company for research expenditures incurred.

Review and Approval of Research Proposals

The procedure to review and approve research proposals ensures that each proposal receives thorough consideration and a prompt response. Proposals considered to fall within the Alberta Coal Research Strategic Plan are discussed in detail with the applicant and are often referred in confidence to one or more outside experts for detailed technical review.
The President of The Coal Association of Canada also reviews a summary of each proposal on a confidential basis and provides his personal views on implications for the coal industry.

An Alberta government interdepartmental group has been established to comment on the implications of the proposed research within its areas of responsibility. This Interdepartmental Group for Coal Research includes representatives from the Energy Resources Conservation Board, Energy and Natural Resources (Alberta Forest Service, Public Lands and Fish and Wildlife divisions), Economic Development, Environment and Workers' Health, Safety and Compensation.

Approval of the research proposals by the Members of the Office of Coal Research and Technology is based on the results of these reviews, the relative funding contributions and the likelihood that the proposed research will contribute to achieving the goals of the Alberta Coal Research Strategic Plan. These projects funded within the Alberta/Canada Energy Resources Research Fund are subsequently submitted to that Committee for approval.

Applications received within the scope of the Alberta Coal Research Grants Program are reviewed by the Alberta Office of Coal Research and Technology to ensure they are consistent with the objective of this program. Applications are then considered in detail by the Coal Technical Review Panel, which makes recommendations to the Office regarding the merits of each application and its associated funding and the extent to which it should be supported by the Office.

Project Management

The Alberta Office of Coal Research and Technology does not have in-house facilities to carry out research projects. Rather, procedures have been established to ensure sound project management by the applicants and financial control of approved projects. Specific agreements are signed for each project which define the terms and conditions under which the project will be conducted and funded. These agreements also define the respective rights of project technology ownership and use.

Staff

Initial appointments to the Office were R. Douglas McDonald as Chairman, and Keith E. Cooper and Garnet T. Page as Members. Keith E. Cooper served until March 1985; Michael A. Ward was appointed Member in May 1985. T.D. Brown represents Energy, Mines and Resources, Canada, as an observer and participates in project reviews.

The Office does not have staff specifically assigned to it but draws on existing positions of the Scientific and Engineering Services Division, Alberta Energy and Natural Resources. All of the staff members of the division have contributed much to the initial progress of the Office.

RESEARCH PROJECTS

A major function of the Alberta Office of Coal Research and Technology is to administer research projects for the development and application of new technologies related to Alberta's coals.

From its inception in January 1984 until March 31, 1985, the Alberta Office of Coal Research and Technology received 25 proposals for new research or pilot-scale development projects. The proposals cover a wide range including exploration, mining, coal preparation and upgrading, combustion, conversion, environment and markets. Six proposals have become approved projects, 12 are under active consideration and four were rejected as outside the scope of the Alberta Coal Research Strategic Plan; two were withdrawn by the applicants and one has been resubmitted under the Coal Research Grant Program.

One proposal is a request from the Canadian Coal Liquefaction Corporation in Edmonton for assistance to construct and operate a six tonne per day pilot plant for coprocessing coal and heavy oil.

Twenty expressions of interest were received; one has become a research project and two have been submitted as formal research proposals. Of the remaining seventeen, nine are being actively encouraged, two are of general interest, four have been withdrawn by the proponents and two were rejected as outside the scope of the Alberta Coal Research Strategic Plan.

In addition to the new research projects approved in 1984/85, the Office also assumed responsibility for ongoing coal research projects funded by the Alberta/Canada Energy Resources Research Fund and by the Department of Energy and Natural Resources.

The following sections describe the projects which have received funding from the Alberta Office of Coal Research and Technology.

Surface Geophysical Coal Exploration

TransAlta Utilities Corporation, Calgary, and other participants

In 1984/85, the program successfully assessed surface geophysical techniques to define subsurface coal seams and the overburden materials. These methods help to provide a reliable three-dimensional picture of subsurface formations, which facilitates mine planning.

The petroleum industry uses surface geophysical techniques extensively in exploration; applying these techniques to coal exploration can lead to siting drill holes more selectively and reducing the number of holes required. Geophysical and drilling results can together provide information on the continuity of coal seams that is more reliable than the interpretation of drill hole results alone.

Several geophysical methods were assessed at two operating coal mines in the Alberta plains region and the results correlated with geological information obtained from borehole logs and air photos. These techniques correctly defined the thickness of overburden and the lateral location of coal subcrops. The glacial overthrusting of strata and its lateral extent were also identified.

Further work is planned for 1985/86 in the plains coal fields, before moving to the foothills region in the third year of the project.

Geophysical methods can provide more reliable data for mine planning and also considerable savings in cost. The geophysical techniques developed during this project are projected to be in common practice in the coal mining industry by 1987.

TECHNICAL HIGHLIGHTS

Test sites for the 1984/85 program were selected at the Highvale and Paintearth mines.

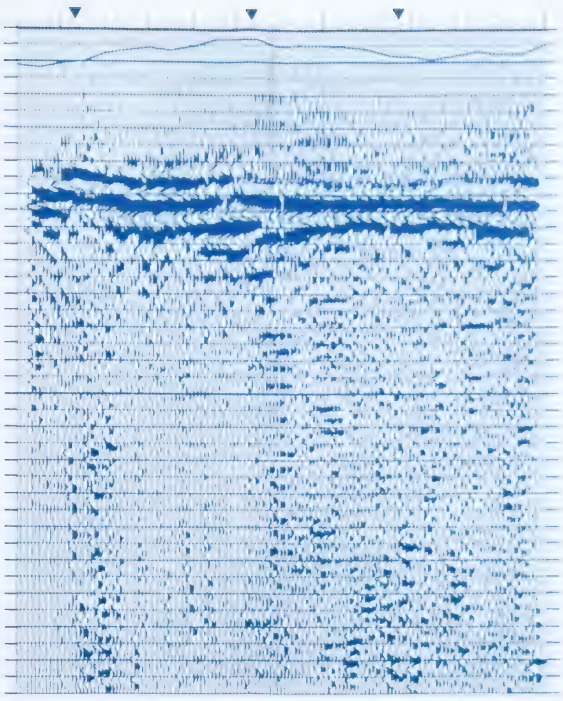
A preliminary glaciotectonic map of the Pit 2 area of the Highvale mine, prepared from airphotos, identified glacially disturbed sediments and was used to locate 5.9 km of geophysical lines. These lines were extended to an adjacent area of pit highwall instability.

At the Paintearth mine, 8.5 km of geophysical lines were located from a study of drillhole data.

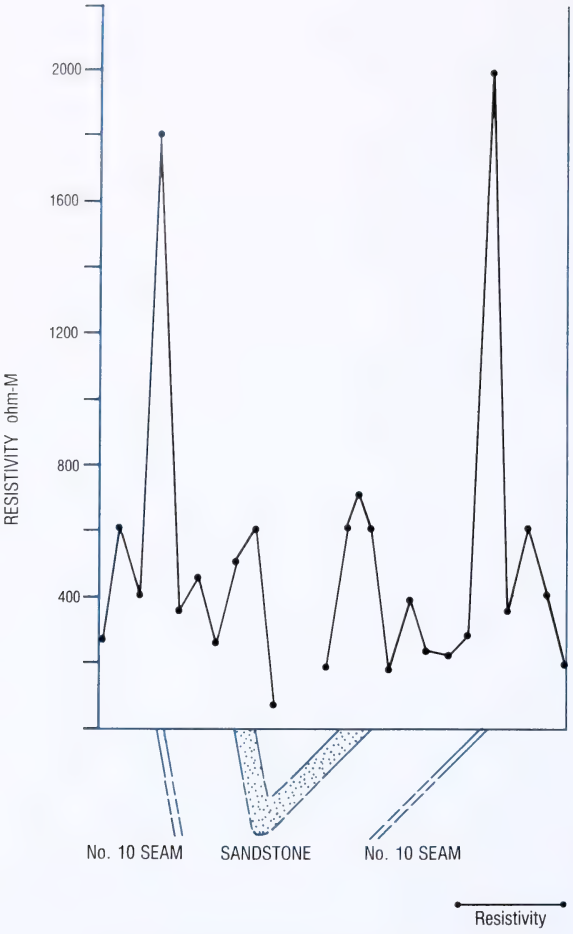
The geophysical techniques assessed in this project include reflection and refraction seismic, direct current and electromagnetic methods.

The reflection seismic technique successfully identified the top and bottom of coal seams and areas of glacial overthrusting under less than 40 m of overburden. Refraction seismic techniques defined the lateral extent of glacially disturbed materials as well as located the water table. Direct current methods determined the depth of coal seams and their lateral extent.

The information from these methods was correlated with data from additional drill holes located on the geophysical lines to provide a reliable three-dimensional picture of subsurface formations.



Highvale mine: Reflection Seismic Time Section identifying coal seam boundaries.



Smoky River Coal Mine: Relationship of resistivity to lithology and structure.

Very Low Frequency Geophysical Methods in Coal Exploration

Smoky River Coal Limited, Grande Cache

The use of very low frequency signals to locate coal seams and fault subcrops in geologically complex mountainous terrain was assessed in this project. Very low frequency transmitting stations, located around the world, are used for marine and aerial navigation. These high power, low frequency signals induce electromagnetic responses related to the conductivity of coal and rock. They can also be used to determine the apparent ground resistivity.

The South Pit area of the Smoky River coal mine was selected for study because of the availability of drill hole and outcrop data, its structural complexity and the variability of its unconsolidated overburden and terrain. The results of electromagnetic and resistivity surveys conducted in the South Pit area have been plotted, interpreted and correlated with the geology.

Very low frequency electromagnetic responses can be used to differentiate between areas of thick and thin overburden. Very low frequency resistivity measurements, together with geological data, can enhance the interpretation of structurally complex coal deposits. Depth of penetration will vary with the conductivity of the overburden. In the South Pit area, unconsolidated overburden greater than 12 metres thick completely masks bedrock responses.

Coal seams are expected to have higher electrical resistivity than the surrounding rock. However, weathering effects or the presence of ground water may significantly reduce the resistivity of coal seams. Additional geological mapping or drilling data must therefore be available to correlate the resistivity responses with the coal measure stratigraphy.

In spite of certain limitations in the technique, this project demonstrates that very low frequency methods, together with drill hole and other geological information, can be a useful tool in the exploration of structurally complex coal deposits.

Coal Mining Research

Coal Mining Research Company, Devon

The Coal Mining Research Company, a private non-profit company, provides industry and government with research and development services related to Canada's coal resources. Research activities include exploration, surface and underground mining, reclamation, coal preparation and health and safety.

Mining research projects funded by the Alberta Office of Coal Research and Technology during 1984/85 included the compilation of a handbook on the measurement and control of mining subsidence. The handbook presents case studies of subsidence damage, prevention and remedial measures applicable to conditions in western Canada.

Tailings disposal is a major environmental problem. A literature survey has been carried out on alternate disposal methods.

A hydraulic testing laboratory was equipped with a computer-controlled 4500-kN compression/tension load frame for uniaxial and triaxial rock testing. Equipment capable of conducting most standard soil mechanics tests was purchased so that the physical properties of overburden materials in surface coal mines can be determined.

Creep Characteristics of Coal

University of Alberta (D.M. Cruden), Edmonton

The mechanical failure of coal under pressure was the focus of this study. Creep is the slow, time-dependent change of the physical dimensions of solid materials subjected to mechanical stress. Creep may result in mechanical failure of coal pillars, which are left in underground mines to support the working area. Creep in complex materials such as coal is difficult to assess but of major concern for the safety of underground miners.

The time-dependent strain for a series of coal samples was determined in a laboratory program. Under constant applied pressure, creep was found initially to decelerate for all specimens tested. After time periods ranging from several hours to several thousand hours, some specimens showed an accelerated creep which led to failure.

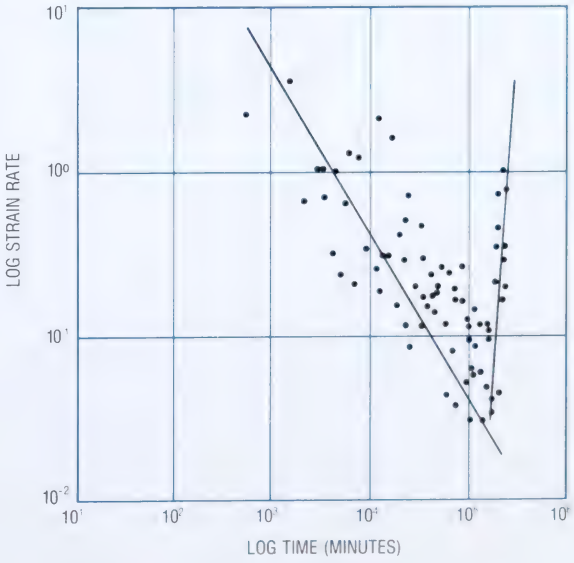
A mathematical model in the form

$$\dot{e} = At^B + Ct^D$$

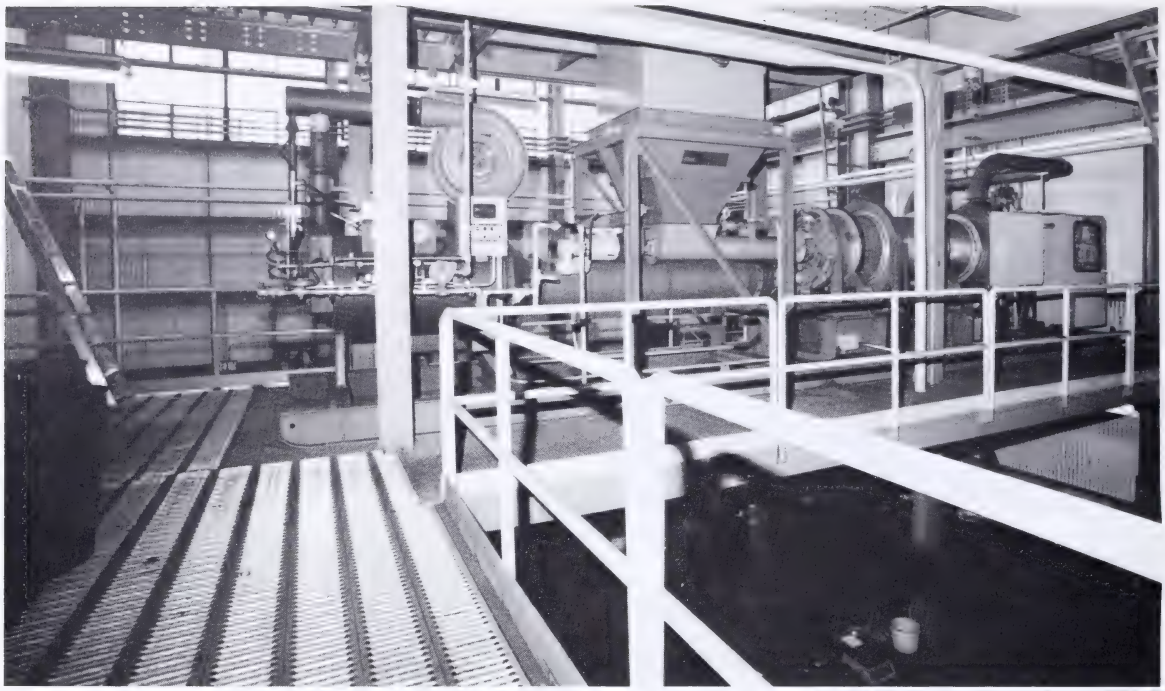
where $\dot{e}$ is the rate of strain
t is time
A, B, C, D, are constants

was developed. Existing computer programs for non-linear regression analysis were found to be unsuitable to analyse the creep data. A new computer program, CPACK, was developed to analyse the experimental results.

Considerable work is still required. The major challenge lies in the highly variable nature of the coal, not only between coal seams, but also within a particular seam. Nevertheless, these results add to the fundamental understanding of the mechanical failure of coal.



Plot of strain rate (micro-strain/min) vs time (min) for Starkey coal sample.



Coal Preparation Research

Coal Mining Research Company, Devon

Western Canadian coals must be dried to reduce their moisture content to required specifications. Laboratory-scale tests were performed on 46 western Canadian coal samples, ranging in rank from bituminous coal to lignite, to establish the relationship between coal rank and thermal drying characteristics. Data from these tests were then used to prepare drying curves. In further tests, a bench-scale dryer was used to predict product moisture and to provide design criteria for coal dryers. In addition, a pilot-scale Roto-Louvre dryer with a capacity of 1 tonne per hour was commissioned to permit larger scale tests. This unit is designed to be easily transported to mine sites for field tests.

In a related project, the problem of readsorption of moisture by thermally dried coals was studied. An environmental chamber to test coals under different conditions of humidity and temperature has been installed.

A further project examined performance fluctuations in coal preparation plants that cause lower productivity and increased costs. These fluctuations are mainly due to variations in raw coal feed. This project will determine the nature and causes of performance fluctuations of a specific plant over an extended period. The results should be applicable to other coal preparation plants in western Canada.

An economic evaluation of cleaning and drying options in coal preparation was undertaken. The objective was to determine optimum combinations of conventional coal preparation and upgrading processes to meet the export market specifications of western Canadian coals. The effects on mining costs of changes in coal preparation, which can be significant, are also evaluated.

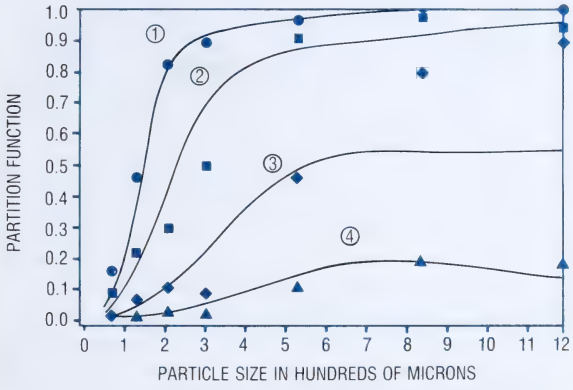
Mathematical Modelling of Auto-Medium Cyclones

Hydrocarbon Research Centre Inc. (L.R. Plitt, and B.C. Flintoff), University of Alberta, Edmonton

This project examined variables affecting the operation of the auto-medium cyclone, in an attempt to improve coal recovery during processing. The sheared and friable coals from the foothills and mountains of western Canada produce a high proportion of coal fines during mining, preparation and handling. Much of this fine coal is lost to tailings, resulting in a costly reduction of marketable coal. This has stimulated research into methods to increase the recovery of fine coal and to treat effluents from coal preparation plants.

An empirical mathematical model of the auto-medium cyclone for the treatment of western Canadian coals has been developed, based on the well-established model for classifying cyclones.

Forty-eight experimental runs were carried out on coal samples from southeastern British Columbia. The cyclone products were screened and analysed. Good correlations have been established between the major cyclone operating and design variables, such as feed rate and pressure, and the parameters of the model. In its present form, the model can be used to reduce the amount of data to be handled in plant operations. Furthermore, it has potential application to the design, simulation, optimization and control of auto-medium cyclone circuits.



Curve	Mean specific gravity of solids
①	1.56
②	1.375
③	1.315
④	1.28

An example of the fit of the first generation cyclone model to the experimental data.

Agglomeration of Low Rank Alberta Thermal Coals

Alberta Research Council, Nisku

Previous work at the University of Alberta and the Alberta Research Council has shown that the quality of Alberta coals including subbituminous coal can be improved by the oil agglomeration process. In this process, finely divided coal particles in a water slurry are coated with oil. The oil-treated coal particles are then attracted to each other and form round agglomerates of coal. The resulting agglomerates contain less moisture and inorganic impurities than the parent coal. The previous work has also shown that Alberta's heavy oil and oil sands bitumen residues are an effective source of oil. The agglomeration process can take place both in stirred tank reactors and during transportation in a pipeline.

The work under this project was directed to establish in more detail the effect of different coal particle size distributions and oil products on the efficiency of the agglomeration process and on the resulting product characteristics.

TECHNICAL HIGHLIGHTS

The optimum median particle size for all coals was found to be in the range of 0.17 mm - 0.30 mm. For subbituminous coals, bitumen-based oils were found to give stronger agglomerates than heavy oil based oils. The optimal process conditions showed greater variation among the five subbituminous coals than among the four bituminous coals tested.

The increase in calorific content and the improved product quality is seen in the accompanying table.

Preliminary results on recovery of volatile components from the oil components of the agglomerates showed that up to 60% of the liquid could be recovered in the form of distillable oil. The calorific value of the agglomerates after stripping of light oil remains essentially unchanged.

COAL CHARACTERISTICS

	COAL SAMPLES	
Run of Mine	**Bituminous** (4 coals)	**Subbituminous** (5 coals)
Ash %	20 - 48	12 - 30
Calorific Value (BTU/lb Air Dried)	7 500 - 10 000	8 600 - 9 200
Agglomerates	**Bituminous** (4 coals)	**Subbituminous** (5 coals)
Ash %	5 - 13	7 - 13
Moisture %	10 - 18	12 - 20
Oil %	6 - 15	7 - 11
Calorific Value (BTU/lb Air Dried)	11 600 - 12 500	11 000 - 12 000

Coal Beneficiation Process

Gulf Canada Ltd., Sheridan Park and Ontario and Union Oil Company of Canada Limited, Calgary

Gulf Canada has developed a patented process applicable to the beneficiation of Alberta plains coal. Coal is immersed in a hot oil residuum obtained from refinery vacuum tower bottoms. As moisture and oxygen are removed from the coal, its heating value increases. The process prevents readsorption of moisture and reoxidation of the product, both of which contribute to spontaneous combustion.

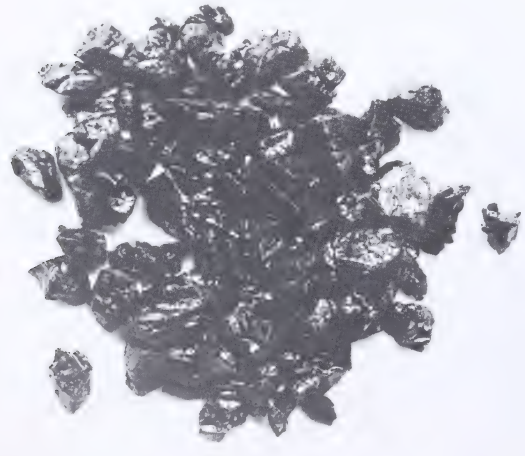
Batch and continuous laboratory tests on samples of Alberta coals are in progress at Gulf Canada's facilities at Sheridan Park, Ontario. Results are encouraging and confirm that immersion in the residuum at 250°C improves the quality of the test coal.

The successful application of this process to the treatment of Alberta coals may improve their marketability and increase sales in Europe and the Pacific Rim countries.

TECHNICAL HIGHLIGHTS

A program has been initiated to develop design data for a 2 to 4 t/d pilot plant at the Obed Mountain Coal Company in Alberta. Batch tests were carried out with Obed Marsh coal to simulate the conditions for a continuous process and to develop process variables including particle size, residuum type, operating temperature and residence time.

Coal with a distribution of particle size in the range of 1 mm to 12 mm was divided into several groups. The batch tests were made on each of the groups to determine the effect of particle size. Coal immersed in residuum at 250°C gives products with residual moisture contents of less than 0.2% with product yields in the range of 93% to 97%. The residuum retained in the product varies with the size fraction but averages 4%.



Combustion of Agglomerated Alberta Coals

Scientific and Engineering Services Division, Energy and Natural Resources, Edmonton and Luscar Ltd., Edmonton

The purpose of this project is to investigate the combustion characteristics of Alberta coals that have been upgraded by the oil agglomeration method. Bituminous and subbituminous coal samples have been selected, and grinding, agglomeration and drying are in progress prior to combustion tests by the Research Division of Ontario Hydro.

ENR/ARC Coal Conversion Research Program

Alberta Research Council, Devon

This program investigated three approaches for the conversion of Alberta subbituminous coals into liquid hydrocarbon products. These are direct liquefaction, coprocessing of coal with heavy oil or bitumen, and partial conversion by pyrolysis.

In previous experiments, Highvale and Vesta coal samples, representative of the two major coal seams, were processed in a batch autoclave. Results indicated that all three approaches were promising, and also that the two major subbituminous coal seams had somewhat different properties. In 1984/85, larger scale semi-continuous and continuous tests were conducted for the most promising processes.

Coal liquefaction is a two-step process. The coal is first dissolved in the solvent, and then the resulting mixture is hydrogenated to liquid products. The optimal conditions for the two steps are different, which led to an interest in examining two-stage liquefaction processes. Test results in a two-stage mode for Highvale coal using potassium molybdate as a catalyst in the first stage and either potassium molybdate or a supported nickel/molybdenum catalyst in the second stage, resulted in overall coal conversion in the range of 80% to 90%. Although Vesta coal was more reactive, similar distillable oil yields were obtained from both coals.

Coprocessing coal and bitumen gives an advantage over conventional coal liquefaction since the bitumen is the solvent. In coal liquefaction, part of the liquefied product must be recycled to act as solvent, effectively reducing the yield and increasing the capital equipment costs.

Coprocessing of Highvale coal with bitumen was examined in a two-stage semi-continuous process mode. The use of carbon monoxide/steam instead of hydrogen as the reducing gas in the first stage gave faster reaction rates. Preliminary analysis of the reaction products indicate significant reaction takes place between the coal and the bitumen.

Pyrolysis is a process for converting coal into gaseous and liquid hydrocarbons, leaving a residual char. Hydropyrolysis process conditions were identified, which resulted in the conversion of up to 10% coal into benzene. The combustion characteristics of the resulting chars varied widely. Some were more reactive than the parent coal, perhaps reflecting changed physical characteristics.

TECHNICAL HIGHLIGHTS

Direct Liquefaction

Test runs with Highvale coal, representative of the Paskapoo formation, in the one-stage mode using anthracene oil as a solvent and either potassium molybdate/dimethyl disulphide or iron oxide/dimethyl disulphide as a catalyst show comparable coal conversions in the range of 87% to 90%. Optimal temperature conditions for both catalyst systems were in the range of 400°C to 455°C with residence time of 50 to 60 minutes. Distillable oil yields up to 40% expressed as the net output on a dry, ash-free coal basis, were obtained. Liquefaction using recycled coal-derived solvent increased the hydrogen-to-carbon ratio for the liquid products and also increased the liquid yield by up to 10%.

Test runs with Vesta coal, representative of the Horseshoe Canyon formation, in the one-stage mode using anthracene oil solvent and potassium molybdate/dimethyl disulphide catalyst, showed coal conversion up to 97%. This is somewhat higher than the Highvale coal, reflecting the higher reactivity of the Vesta coal. Distillable oil yields were similar to the Highvale coal. The increased conversion resulted in higher quantities of CO, CO_2 and light hydrocarbons. Nevertheless, the optimal temperature and time conditions for Vesta coal seem similar to those for Highvale coal. Test results using recycled coal-derived solvent were similar to those found for Highvale coal.

With first-stage residence times below 10 minutes, and temperatures in the range of 420°C to 470°C, distillable oil yields were very low, possibly reflecting insufficient coal dissolution. The use of supported nickel/molybdenum catalyst in the second stage increased the distillable oil yield to the range of 10%. With residence times of 30 minutes and temperatures in the range of 430°C to 450°C in the first stage, and 45 minutes and 430°C using a supported nickel/molybdenum catalyst in the second stage, distillable oil yields up to 30% were obtained. Product quality was similar to the one-stage process. The effect of recycled coal-derived solvent was not determined.

Coprocessing of Coal and Bitumen

Experiments with Highvale coal and Suncor bitumen in batch autoclaves compared the effectiveness of carbon monoxide/steam with hydrogen as the reducing gas during the first stage of a two-stage process. Potassium carbonate was used as a catalyst for the carbon monoxide/steam tests and ferric oxide/dimethyl disulphide for the hydrogen tests. In the temperature range from 370°C to 410°C, the carbon monoxide/steam atmosphere increased the coal solubility by 20% to 30% up to the range of 70% to 85%. The effect was more pronounced at short residence times.

Slurry produced from the first-stage experiments was further treated in batch autoclaves with one of three different catalyst systems: ferric oxide, potassium molybdate or supported nickel molybdenum, each with a dimethyl disulphide activator. A residence time of 30 minutes at 390°C was used for the first stage and 60 minutes at 440°C for the second stage. Distillable oil yields over 60%, expressed for the coprocessing mode as the output on a dry ash-free feed basis, were obtained with all three catalyst systems.

Semi-continuous two-stage experiments were carried out in a hot charge/discharge autoclave system. A carbon monoxide/steam atmosphere was used in the first stage and hydrogen in the second stage. Catalyst combinations and operating conditions were similar to those in the batch autoclave tests. Coal conversion exceeded 90% and distillable oil yields approached 65%.

Hydropyrolysis

The hydropyrolysis bench unit is an entrained flow reactor feeding up to 2 kg/h of coal into a preheated gas stream at pressures up to 10.8 MPa and temperatures up to 800°C.

The current test program concentrated on evaluating the effect of operating conditions on the product distribution from Highvale coal. Modifications to the bench unit to ensure a uniform coal feed led to an increase in benzene yield from 4% to 8%. In subsequent tests, a benzene yield of 10% daf coal was achieved. Other major products included methane, ethane, carbon oxides, tar and char.

Depending on the hydropyrolysis conditions, the heating value of the residual chars was 27 000 to 29 000 kJ/kg compared to 20 000 kJ/kg for Highvale coal. The intrinsic oxidation reactivity and combustibility of these chars was examined. The reactivity of the chars ranged from 0.3 to 2.9 times the reactivity of the parent coal.

Hydroprocessing Coal-Based Liquids

Hydrocarbon Research Centre Inc. (F.D. Otto and I.D. Dalla Lana), University of Alberta, Edmonton

The effects of different catalysts on a process to remove nitrogen from coal-based liquids were investigated in this project. The usual method for removing sulphur and nitrogen from heavy oil feedstocks and from coal-derived liquids is catalytic hydrogenation. Denitrogenation generally requires more extreme conditions than desulphurization and thus dictates the processing variables. The use of a proven nitrogen-containing organic compound, blended with relatively non-reactive heavy atmospheric gas oil, simplifies experimental studies of catalytic hydrodenitrogenation.

The experimental approach used in this project demonstrated its appropriateness for catalyst evaluation in hydroprocessing of coal-derived liquids and for determination of the important chemical parameters.

TECHNICAL HIGHLIGHTS

This project investigated the catalytic hydrodenitrogenation of quinoline blended with a heavy atmospheric gas oil using several different commercial catalysts. Following an initial catalyst screening, detailed measurements of the reaction rate as a function of concentration of quinoline, temperature and pressure were carried out in a well-stirred flow reactor using a quadrilobed nickel-molybdenum catalyst. Additionally, the catalytic hydrodenitrogenation of a Saarbergwerke coal liquid provided a real-world measure of the activity of this catalyst.

The experimental kinetic studies encompassed temperatures from 380°C to 420°C, hourly space velocities from 11 ml/h to 24 ml/h per gram of catalyst, and pressures from 7.0 MPa to 17.3 MPa. Catalyst comparisons were standardized at 13.9 MPa, 400°C and 11 ml/h per gram of catalyst. Since the experiments were conducted at near saturation levels of hydrogen dissolved in the oil, hydrogen solubility data at reaction conditions were also obtained.

The nickel-molybdenum catalysts were clearly superior. The optimum nickel-molybdenum ratio was about 0.24. Promotion of a nickel-molybdenum commercial catalyst by fluorine resulted in a substantial reduction of hydrocarbon gas formation without loss of overall hydrodenitrogenation activity. Hydrodenitrogenation involves gas-liquid phases contacting a solid catalyst and the reaction rates are often limited by diffusion of reactants or products within the pore structure of the catalyst pellets. The quadrilobed nickel-molybdenum catalyst, designed to reduce internal mass transfer resistance, exhibited the best activity of all catalysts tested. Below feed nitrogen contents of 0.3 wt%, the hydrodenitrogenation of quinoline exhibits first order rate behavior; but for higher concentrations the presence of additional nitrogen exerts an inhibiting rate effect. Simple kinetic models were developed which correlated with the experimental reaction rates over the entire range of investigated variables.

Supercritical Gas Extraction of Coal in an H-Donor System

Hydrocarbon Research Centre Inc. (N. Berkowitz), University of Alberta, Edmonton

The study investigated the partial conversion of coal to upgradable liquid hydrocarbons by supercritical gas extraction with water in the presence of carbon monoxide. In this reaction, the required hydrogen is furnished by the well-known shift reaction between water and carbon monoxide, represented by

$$H_2O + CO \rightleftharpoons H_2 + CO_2.$$

The process was investigated using two coals—a Saskatchewan lignite and an Alberta bituminous coal—in a one-litre autoclave assembly.

Experimental results show that conversion to primary coal liquids and small amounts of gas could range as high as 50% and 35% for the lignite and bituminous coals respectively. In both cases, conversion could be substantially enhanced by adding a once-through disposable catalyst, such as ferric chloride or ferric oxide, in amounts of 3% to 5%. The catalyst also allowed extraction at pressures as low as 13 to 14 MPa instead of the 20 to 23 MPa required for maximum conversion without a catalyst.

The residual char may be suitable for direct combustion in existing pulverized-fuel boilers.

Coal Liquefaction Feasibility Study

Contar Systems Engineering Ltd., Edmonton,
Canadian Utilities Ltd., Edmonton,
Luscar Ltd., Edmonton and Gesellschaft fuer Kohleverfluessigung mbH, Federal Republic of Germany

The study comprised a conceptual design, capital and operating cost estimates and a financial analysis of a coal/oil coprocessing facility in Alberta. The process flow is based on a combination of technology developed by the Alberta Research Council and Gesellschaft fuer Kohleverfluessigung. The design of the facility is based on the conversion of 4 000 tonnes per day of run-of-mine Alberta subbituminous coal and 30 000 barrels per day of Lloydminster heavy oil into 42 000 barrels per day of refined liquid fuel products.

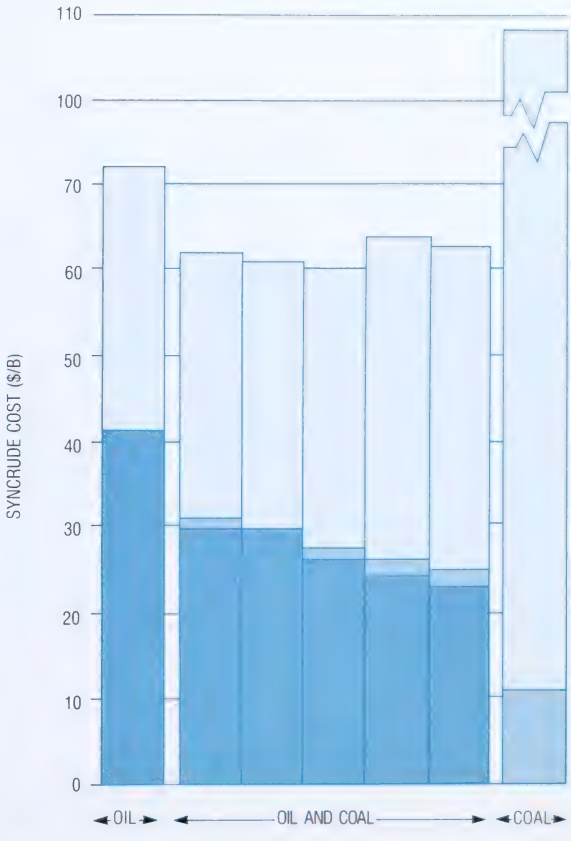
The results of the financial analysis indicate that the economics of the process are comparable with heavy oil upgrading. Before considering further large-scale development of this selected process, the potential of other promising process alternatives is being examined.

Economic Evaluation of Coal/Oil Coprocessing

HRI, Inc., Gibbsboro, New Jersey, U.S.A.

The project examines the economics of using coal and natural gas to produce high quality synthetic crude from a remote, integrated heavy oil productions/upgrading site. Seven process options were investigated using feedstocks ranging from all heavy oil to all coal. One option was the use of coal for steam generation as an alternative to natural gas.

The least attractive option is direct coal liquefaction, because of the high investment cost. Heavy oil upgrading and coal/oil coprocessing are cost equivalent, but the latter offers higher synthetic crude yields from the heavy oil and more feedstock flexibility.



Comparative costs of Syncrude production from oil, coal and coprocessing of oil and coal (after Hydrocarbon Research Inc.).

Synthetic Fuels Program
SRI International, Menlo Park, California, U.S.A.

The Synthetic Fuels Program in which Alberta Energy and Natural Resources participated was a three-year program sponsored by 19 companies and organizations. The program examined the role of synthetic fuels, including those derived from oilsands and coal, in the context of the resources, supply, demand and price of conventional oil and gas. A series of annual reports were published, the last in 1984.

The program concluded that market forces will continue to encourage selected synthetic fuel projects, but that these fuels will not make a major contribution to energy supplies until the next century. Also, the consumption of coal for electric power generation is expected to increase, constrained only by demand and environmental considerations.

Coal Slurry Pipeline Research
Pembina Resources Ltd., Calgary

Transportation cost is a significant portion of the cost of Alberta thermal coals delivered to eastern Canada and overseas markets. This project by Pembina Resources Ltd., supported by experimental work at the Alberta and Saskatchewan Research Councils, investigates the potential of slurry pipelines as an alternative to railroad transportation. The project compares the engineering aspects and costs of five alternative slurry technologies to transport 2 million tonnes per year of dry coal for short, intermediate and long distances. The five alternatives are:

- slurries with a fine particle size distribution
- slurries with an intermediate particle size distribution
- slurries with a coarse particle size distribution
- dense phase coal water slurries
- agglomerated coal slurry

The results indicate that the cost of pipeline transport depends to a large extent on whether the coal must be dried or dewatered at the end of the pipeline and also on the specific type of slurry transported.

The findings are summarized in the accompanying table, which provides an estimate of the direct operating costs including slurry preparation but excluding mining for transporting 2 million tonnes per year of coal through pipelines of various distances. Recovery of capital investment has not been included but can be expected to have a significant effect. Except as noted, the costs do not include dewatering or drying.

The longest distance corresponds to the distance to transport coal from Alberta to the west coast of Canada. The intermediate distance corresponds to the distance required for a representative industrial application within Alberta. The two shorter distances are considered for raw coarse coal transport.

The cost of the 300 kilometre case varies depending on whether it is run-of-mine coal or cleaned coal.

The relatively high cost for pipelining agglomerated coal may reflect difficulties associated with modelling the flow characteristics of this slurry.

Comparison between the direct operating costs for pipeline transport and the cost of rail transport is difficult. Rail costs do not include the cost of coal cleaning, but this is included in the pipeline costs. Also, in most cases, the preparation of a pipeline transportable coal slurry requires additional grinding. Consequently, even after drying, the pipelined coal has a smaller particle-size distribution than does coal transported by rail. Cost savings to the customer may result, depending on the use of the coal.

The study, despite its limitations, provides a useful reference for more detailed investigations of specific coal slurry pipeline applications.

ESTIMATED DIRECT COST FOR SLURRY PIPELINING ($Cdn/tonne-km)

	5 km	25 km	300 km	1000 km
Fine coal slurry			$0.01-$0.03	$0.012-$0.015 $0.021-$0.023 (with drying)
Intermediate coal slurry				$0.012-$0.015 $0.021-$0.023 (with drying)
Coarse coal slurry	$0.19	$0.08		
Dense phase coal slurry				$0.035
Agglomerated coal slurry			$0.056	

Coal Conversion Waste Water Technology
Hydrocarbon Research Centre Inc. (S.E. Hrudey), University of Alberta, Edmonton

The anaerobic biological treatment of waste-water from coal conversion processes is the focus of this project. Biological treatment with anaerobic micro-organisms which live in the absence of oxygen is preferable to treatment with aerobic forms which require oxygen to live, because anaerobic treatment produces methane and generates a smaller quantity of sludge. Sludge disposal has important economic and environmental implications for waste water treatment plants.

Waste waters from coal conversion processes, including coal liquefaction, exhibit high concentrations of phenolic compounds. Techniques were developed and used to examine the anaerobic degradation of various phenolic compounds that would be found in such waste waters.

The study concluded that anaerobic biological treatment could be used successfully to treat most phenolic waste from a coal conversion facility. This project represents a significant advance in understanding the anaerobic biological treatment of waste waters from coal conversion processes.

Imported Steam Coal Demand
The Institute of Energy Economics, Tokyo, Japan

This multi-sponsored study examines the potential demand in 1990 for imported thermal coal for six Asian markets: Japan, Korea, Taiwan, Hong Kong, Malaysia and the Philippines.

The study considers historical and forecasted economic growth rates, as well as coal demand by industrial sector. Electric power generation is by far the most important use of coal, accounting for almost 70% of total demand.

The study concludes that the total demand for imported thermal coal in the six market areas will rise from 21.8 million tonnes in 1982 to 56 million tonnes in 1990. The largest increases will be in Japan, Hong Kong and Korea.

Coal Technology Information Centre
Alberta Research Council, Devon

The Coal Technology Information Centre is responsible for collecting and disseminating technical information related to coal. Technical areas include exploration, mining, preparation, utilization and transportation, as well as coal conversion and environmental factors associated with coal. Holdings include journals and books related to western Canadian coal.

The Information Centre publishes a bi-weekly current acquisitions bulletin which is distributed to users in industry, research organizations and government. It also prepares abstracts of technical literature related to western Canadian coal. Specialized literature searches and bibliographies are performed on request.

Devon Coal Research Centre
Devon

With the completion of the Devon Coal Research Centre in 1984, much of the coal-related research that was dispersed throughout the Edmonton region is now at one location. An objective in providing capital funds for the building was not only to provide a first-rate facility, but also to encourage research scientists in related areas to share ideas and resources.

The Coal Department of the Alberta Research Council, the Coal Mining Research Company and the CANMET coal laboratories of Energy, Mines and Resources, Canada share the 16 000-square-metre complex in Devon, near Edmonton.

The centre has three components: a pilot plant, an office/laboratory complex and a high-head laboratory. The pilot plant is an industrial-scale research facility with space for testing mining equipment and coal processing technology. Within the office/laboratory complex are standard analytical laboratory facilities, offices, a library and meeting rooms. In the high-head laboratory, two containment cells provide space behind heavy steel walls for research at high temperatures and pressures. Special measures were taken to ensure the control of coal dust and cross-contamination in the building.

PROJECT EXPENDITURES

During the fiscal year April 1, 1984 to March 31, 1985, expenditures on approved research projects totalled $4 301 650, of which $4 257 707 was provided from the Alberta/Canada Energy Resources Research Fund. Administration costs, also provided from the Alberta/Canada Energy Resources Research Fund, were $159 268, representing 3.7% of the research expenditures. In addition, $1 429 466 was expended from the Alberta/Canada Energy Resources Research Fund on the construction of the Devon Coal Research Centre.

In addition to these funding contributions, the coal industry and other organizations contributed $2 155 917 or 33.4% of the total research expenditures of the approved projects.

Funding contributions to approved projects are shown in Table 1. Cumulative expenditures to March 31, 1984 include the period of time beginning April 1, 1977. Projected future contributions include funding approved-in-principle for multi-year projects.

TABLE 1 — Funding contributions to approved projects

PROJECTS	Cumulative To March 31, 1984 ($)	April 1, 1984 To March 31, 1985 ($)	Projected Future Contributions ($)	Total ($)
Exploration				
Surface Geophysical Coal Exploration TransAlta Utilities Corporation	Nil	96 915	227 095	324 010
VLF Geophysical Methods in Coal Exploration Smoky River Coal Ltd.	Nil	4 426	10 420	14 846
Mining				
Coal Mining Research Coal Mining Research Company	1 259 285	278 838	455 731	1 993 854
Creep Characteristics of Coal University of Alberta, (D.M. Cruden)	14 567	1 892	Nil	16 459
Preparation and Upgrading				
Coal Preparation Research Coal Mining Research Company	3 279 744	1 188 731	198 429	4 666 904
Mathematical Modelling of Auto-Medium Cyclones Hydrocarbon Research Centre, (L.R. Plitt)	95 711	Nil	Nil	95 711
Agglomeration of Low Rank Alberta Thermal Coals Alberta Research Council	136 754	Nil	Nil	136 754
Coal Beneficiation Process Gulf Canada Ltd.	Nil	68 546	1 481 454	1 550 000
Combustion				
Combustion of Agglomerated Alberta Coals Energy and Natural Resources	Nil	2 061	56 200	58 261
Conversion				
ENR/ARC Coal Conversion Research Program Alberta Research Council	11 550 637	2 240 729	906 671	14 698 037
Hydroprocessing of Coal-Based Liquids Hydrocarbon Research Centre, (F.D. Otto)	80 056	4 607	Nil	84 663
Supercritical Gas Extraction of Coal in an H-Donor System Hydrocarbon Research Centre, (N. Berkowitz)	61 819	5 473	Nil	67 292
Coal Liquefaction Feasibility Study Contar Systems Engineering Ltd.	Nil	90 553	Nil	90 553
*Economic Evaluation of Coal/Oil Coprocessing Hydrocarbon Research Inc.	Nil	43 943	4 174	48 117
*Synthetic Fuels Program SRI International U.S.A.	48 220	Nil	Nil	48 220
Transportation				
Coal Slurry Pipeline Research Pembina Resources Ltd.	114 903	150 333	22 717	287 953
Environment				
Coal Conversion Waste Water Technology S.E. Hrudey, Hydrocarbon Research Centre	87 890	Nil	Nil	87 890
Markets				
*Imported Steam Coal Demand The Institute of Energy Economics, Japan	5 340	Nil	Nil	5 340
Other				
Coal Technology Information Centre Alberta Research Council	258 583	123 537	189 000	571 120
Devon Coal Research Centre	17 510 606	1 429 466	100 000	19 040 072
TOTAL	**34 504 115**	**5 730 050**	**3 651 891**	**43 886 056**

* Not funded by A/CERRF

The change in funding contributions for coal-related research provided through Energy and Natural Resources is shown in Figure 1, as well as contributions from industry and other organizations.

The change in emphasis of research funding through the Alberta Office of Coal Research and Technology, reflecting the priority on market-oriented objectives, is seen in Figure 2, which compares the distribution of funding contributions by area of research for the past two fiscal years and projected for 1985/86.

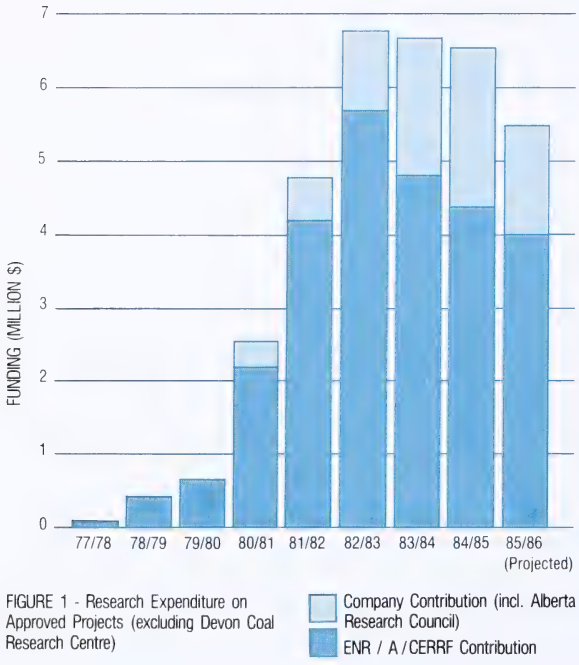
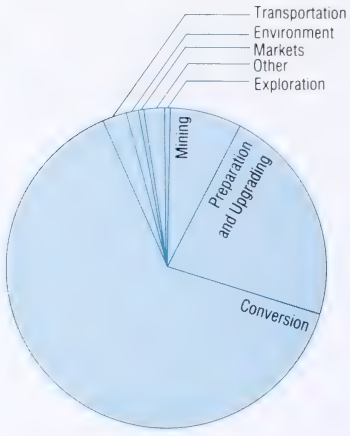
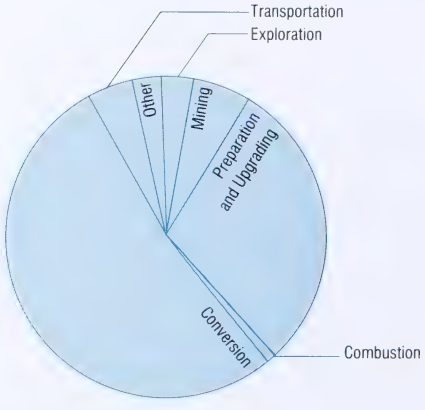


FIGURE 1 - Research Expenditure on Approved Projects (excluding Devon Coal Research Centre)

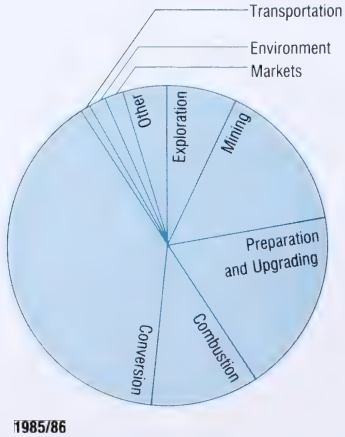
FIGURE 2: Distribution of ENR / A / CERRF Funding Contributions



1983/84



1984/85



1985/86
(Projected)

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